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14. ABSTRACT

Traditionally, the principles and practices of anesthesia have been taught using seminars and lectures to supplement clinical training. There is no substitute for case-based experience; however, recent innovations in computer technology provide high fidelity, realistic simulators, which are being used in many anesthesia programs. Research using simulation technology analyzes its use as an evaluation tool in the assessment of competence and human performance; however, there is a need to better define the role for simulation-based programs in professional nurse anesthesia education. The purpose of this study was to evaluate the effectiveness of integrating the anesthesia patient simulator with the traditional lecture in nurse anesthesia education. The study measured the potential benefits of knowledge assimilation and retention using the human patient simulator (HPS) in an anesthesia pharmacology course compared to the traditional classroom approach. The sample group for this study consisted of GSN nurse anesthesia students enrolled at the Uniformed Services University of the Health Sciences in Bethesda, Maryland. Outcome measures included the completion of a twenty item pre-test to measure each student's baseline knowledge prior to participating in a 1.5-hour pharmacology teaching session. Knowledge retention was measured by the results of each student's 20-item post examination scores. Comparison data of the pre and post-examination scores within each teaching group was analyzed using a paired t-test. An independent t-test was used to statistically analyze the absolute difference in learning between using Likert type items, and additional open-ended items, exploring student expectations, course strengths and weaknesses, and recommendations for future courses. Knowledge equivalence was shown in the two groups, with baseline pretest scores showing no statistically significant difference ($t = .781$, $p = .453$). There was statistically significant improvements in learning within each teaching group (simulator $t = 4.66$ $p = .005$, classroom $t = 4.84$ $p = .005$). Greater improvement was noted in the HPS group, with a mean score 4.5 higher than the traditional classroom group, approaching statistical significance ($t = 1.89$, $p = .088$). The results of this study suggest that the active process of learning anesthesia pharmacology concepts using the HPS serves as a powerful adjunct, and may be superior to the traditional lecture method of teaching anesthesia pharmacology to nurse anesthesia students.

15. SUBJECT TERMS

Human patient simulator; adult learner; procedural memory; skill; induction agent; pharmacokinetics; pharmacodynamics

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ABSTRACT

Traditionally, the principles and practices of anesthesia have been taught using seminars and lectures to supplement clinical training. There is no substitute for case-based experience; however, recent innovations in computer technology provide high fidelity, realistic simulators, which are being used in many anesthesia programs. Research using simulation technology analyzes its use as an evaluation tool in the assessment of competence and human performance; however, there is a need to better define the role for simulation-based programs in professional nurse anesthesia education. The purpose of this study was to evaluate the effectiveness of integrating the anesthesia patient simulator with the traditional lecture in nurse anesthesia education. The study measured the potential benefits of knowledge assimilation and retention using the human patient simulator (HPS) in an anesthesia pharmacology course compared to the traditional classroom approach. The sample group for this study consisted of GSN nurse anesthesia students enrolled at the Uniformed Services University of the Health Sciences in Bethesda, Maryland. Outcome measures included the completion of a twenty item pre-test to measure each student's baseline knowledge prior to participating in a 1.5-hour pharmacology teaching session. Knowledge retention was measured by the results of each student's 20-item post examination scores. Comparison data of the pre and post-examination scores within each teaching group was analyzed using a paired t-test. An independent t-test was used to statistically analyze the absolute difference in learning between using Likert type items, and additional open-ended items, exploring student expectations, course strengths and weaknesses, and recommendations for future courses. Knowledge equivalence was shown in the two groups, with baseline pretest scores showing no statistically significant difference ($t = .781$, $p = .453$). There was statistically significant improvements in learning within each teaching group (simulator $t =$

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Key Words: **Human patient simulator, adult learner, procedural memory, skill, induction agent, pharmacokinetics, pharmacodynamics**

THE EFFECTIVENESS OF THE HUMAN PATIENT SIMULATOR IN TEACHING
ANESTHESIA PHARMACOLOGY TO FIRST YEAR NURSE ANESTHESIA STUDENTS

by

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PREFACE

This research was conducted to determine the effect of using the Human Patient Simulator (HPS) in teaching anesthesia pharmacology to first year nurse anesthesia students as compared to the traditional lecture method of teaching. The purpose was to reveal the use of the HPS as a powerful adjunct, if not a superior method, to the traditional lecture style of teaching anesthesia pharmacology. It was designed to further define the role of the HPS in professional nurse anesthesia education.

DEDICATION AND ACKNOWLEDGMENT

I dedicate this thesis to my husband, Jim and my children, Casie Lorraine and Erik Keelan.

Without their love, encouragement, and support, this paper and the completion of this strenuous program would not have been possible. They sacrificed as much as I have, but we all have truly grown into stronger and better people during these past 30 months, realizing that nothing worthwhile comes easily. I would also like to acknowledge my committee members- Dr Eugene Levine, CAPT Cynthia Cappello, LTC Paul Austin, and Mr John Connelly, for their guidance and support throughout this project.

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HUMAN PATIENT SIMULATORS IN NURSE ANESTHESIA

The Effectiveness of the Human Patient Simulator in Teaching Anesthesia Pharmacology to First
Year Nurse Anesthesia Students.

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Human Patient Simulators in Nurse Anesthesia Education

CHAPTER I- INTRODUCTION

Background

Nurse anesthesia dates back to the mid-1800s when educational preparation consisted of an informal apprenticeship (Hamrick, Spross, & Hanson, 1996). The present preparation requires a more standardized curriculum of a rigorous nature to insure competence in a highly demanding field. The change in the health care delivery system and increased technology are impacting the educational needs of the certified registered nurse anesthetist (CRNA). The complex acuties of operative patients also impacts anesthesia practice. The practice and distribution of nurse anesthetists are additional factors, which influence their educational needs.

A study of CRNAs supports that they are the most prevalent anesthesia providers in rural and/or medically underserved areas in the United States (Fallacaro, 1997). Rural facilities are often smaller with fewer resources, yet the patient populations generally have a higher incidence of chronic disease and morbidity than metropolitan area populations (Fallacaro & Crosby, 2000).

Certain pathological conditions can lead to critical incidents when a patient is under anesthesia. The rarity of such conditions or events challenges traditional methods of educational preparation. Furthermore, although critical events in anesthesia occur infrequently, when they do occur they often can be life-threatening (Gaba, Maxwell, & DeAnda, 1987).

Complex skills are often needed to respond effectively to rare critical anesthesia events. These skills can be practiced using human patient simulators (HPS) which can offer the potential

to support or enhance current methods of teaching by offering experiential, problem-based learning in rare and critical episodes (Gaba, Fish, & Howard, 1994).

A key component of nurse anesthesia is critical thinking- choosing and implementing effective solutions to problems faced in clinical practice. Techniques of developing clinical proficiency in nursing anesthesia are crucial and should occupy a substantial portion of the nurse anesthesia curricula. The gap which exists between theoretical knowledge and clinical practice has suggested recent changes in the content of nurse anesthesia programs.

The integration of the HPS with traditional lecture series, in combination with a quality clinical learning environment, can aid in developing competent nurse anesthetists. This becomes especially important to the CRNA working in clinical environments lacking resources and personnel, as they must rely heavily on their own knowledge and experience, which is often derived from their professional educational preparation.

Purpose

The purpose of this research is to determine the effectiveness of a Human Patient Simulator (HPS) as a teaching tool for first year nurse anesthesia students and evaluate its impact on nurse anesthesia students' critical thinking skills, including the assimilation and retention of specific pharmacology knowledge.

An important area of future study is to examine the impact of simulator training on assimilated cognition and retention of knowledge. It has yet to be quantified that simulator training improves clinical performance or averts catastrophic events because practitioners react differently in stressful situations. It has been shown, however, that cognitive functioning, in general, including critical thinking processes, deteriorate under stress which cause the

practitioner to fall back on simpler, general knowledge (Svenson & Maule, 1993). Conditions such as distractions, task complexity, emotional arousal, and information overload can all occur in the nurse anesthetists' environment, leading to judgmental heuristics to simplify the cognitive task rather than considering the complex details(Bodenhausen, 1990). It has been shown that nurses rely heavily on implicit knowledge to inform their clinical practice (Miller, 1985; Grossman & Hooton, 1993).

According to Mines and Kitchener (1986), general cognitive functioning does not change abruptly in adulthood. To function at a new level requires specific skills, which must be built. The building of these skills takes time and effort. This concept can be applied to the registered nurse embarking in the advanced career field of nursing anesthesia. The HPS can serve as an excellent educational tool to provide knowledge, develop critical thinking skills, and improve procedural memory for the nurse anesthesia student. The use of the HPS to teach first year nurse anesthesia students leads to an important question.

Research Question

1. Does experiential-learning with the Human Patient Simulator enhance the nurse anesthesia student's knowledge retention of anesthesia pharmacology concepts as evidenced by improved performance on a twenty-item written examination?

Conceptual/ Theoretical Framework

Fischer's Skill theory (1980) describes newly acquired cognitive development of adults as being determined by environmental conditions. Only with practiced skills in familiar domains and with environmental support for high-level performance will most people perform at optimum levels. Fischer stresses the importance of practice in building higher skill levels. It takes work to

build skill. There is no automatic transformation of skills to a new level. The person must actively construct every new skill because skills do not freely emerge without effort.

Malcolm Knowles' Adult Learning theory (1984) identifies principles unique to the adult learning experience. Learning is most productive when the student is ready to learn. The learning readiness of adults arises primarily from their roles, tasks, and identity where learning is a process that needs to have immediate application. Although motivation is internal, the instructor can create climates, which will nurture motivation. Learning is most effective when it builds on what the student already knows or has experienced. Learning is most effective when students are aware of what they need to learn. Learning is made easier and more relevant by using a variety of training methods and techniques. Hands-on simulation participation allows for a learning context designed around "inquiry". Listening is never enough. Understanding must occur through the use of experience and interaction. According to Knowles, adult education focuses on preparing the student for change and enabling the student to perform effectively within an organization (1990).

Traditionally the principles and practice of anesthesia have been taught using seminars and lectures to supplement clinical training. Problems exist when lecturing is not accompanied by discussion, questioning, or immediate practice. Lecture formats often do not require the student to think critically. Interactive learning can assist the nurse anesthesia student in successfully transitioning from the classroom to the clinical arena.

Simulation provides the opportunity to incorporate didactic anesthesia into a clinical-like setting by offering an experiential learning opportunity in a reproduced environment. To properly prepare nurse anesthetist students for a successful transition into the real world, their

educational opportunities must facilitate learning that is compatible with actual clinical practice conditions. Training with the HPS allows creation of clinical scenarios and teaching of factual knowledge similar to what the students will encounter in the clinical setting. The proficient practitioner must possess both declarative and procedural knowledge. Declarative knowledge is factual, often presented in forms of didactic teaching or from textbooks. Procedural knowledge, the “knowing how”, includes information about the execution of various actions. Procedural knowledge is acquired from direct instruction or repeated experiences.

Variables of Interest

Independent variable- Human patient simulator (HPS)

Conceptual definition- A whole body mannequin with interactive driving mechanical and computer software.

Operational definition- A realistic representation of a clinical situation using a computerized mannequin in which a student actively participates, applies previously learned knowledge, and receives feedback without concern with real-life consequences (Erler & Rudman, 1993).

Dependent variable- Post-test examination scores.

Conceptual definition- A problem-based, written case simulation designed to evaluate and to assess assimilation of knowledge.

Operational definition- A written clinical examination developed to provide a standardized, objective measurement of pharmacology knowledge presented during course

instruction (Hardin & Gleeson, 1975; Stillman & Swanson, 1986; Sewartz, Witzke, & Donnelly, 1998).

Other terms relevant to study

Adult learner

Conceptual definition- A mature student who brings motivation, professional and life experiences, and attitudes to the classroom. (Adult Learner Task Force, 1998)

Operational definition- A nurse anesthesia graduate student who requires interactive, relevant, and problem-oriented approaches to learning.

Critical incidence

Conceptual definition- Fault-finding occurrence.

Operational definition- A human error or equipment failure that could lead (if not discovered or corrected in time) to an undesirable outcome, ranging from increased length in hospital stay to death (Gaba, Fish, & Howard, 1994).

Procedural memory

Conceptual definition- A type of implicit memory where one learns perceptual psychomotor skill and acquisition of rules and sequences (Mesulam, 2000).

Operational definition- The necessary steps or rules of a procedure that one remembers to successfully accomplish a required task.

Implicit memory

Conceptual definition- Memory independent from conscious recollection; Memory is inferred indirectly through a faster or better performance with certain tasks (Mesulam, 2000).

Operational definition- The necessary memory that involves perceptual strategies.

Skill

Conceptual definition- The ability to use one's knowledge effectively and readily in execution or performance.

Operational definition- A skill is identified as one measure required for competent, safe, and effective administration of anesthesia and necessary to obtain board certification.

Pharmacokinetics

Conceptual definition- The quantitative study of the absorption, distribution, metabolism, and excretion of injected and inhaled drugs and their metabolites.

Operational definition- The study of the body's effect on the drug which determines variability in drug responses between patients, reflecting individual differences in absorption, distribution, and elimination.

Pharmacodynamics

Conceptual definition- The study of the intrinsic sensitivity or responsiveness of receptors to a drug and the mechanisms by which these effects occur.

Operational definition- The study of the drug's effect on the body, determined by measuring plasma concentrations required to evoke specific pharmacological responses.

Assumptions and Limitations

Assumptions:

1. First year nurse anesthesia students will not have prior knowledge or experience with the anesthesia pharmacology topic/simulator experience.
2. First year nurse anesthesia students will perform to the best of their abilities during the pre and post- examination.
3. The results from the randomized sample can be generalized to the population of first year nurse anesthesia students utilizing computerized human patient simulators.

Limitations:

1. Small sample size- limits generalizability to other populations.
2. Sample of convenience- limits generalizability to other populations.
3. Lack of control over personal variables. (prior knowledge, motivation, commitment, state of health)
4. Timing of lecture/simulator series.

Summary

The HPS can serve as a powerful tool in the education of student nurse anesthetists by improving the ability to transfer anesthesia theory into clinical practice. The US Department of Health and Human Services reported in 1991 by the year 2000, an adequate number of trained certified registered nurse anesthetists (CRNAs; 1,800 per year from 1991-2000) could save healthcare consumers \$1 billion dollars annually (Jordan, 1991). To meet this

goal, it is imperative that nurse anesthesia graduate programs produce uniquely qualified anesthesia providers.

Through the use of Fischer's skill theory and Knowles' adult learning theory, the effectiveness of Human Patient Simulators as teaching tools in nurse anesthesia education will be analyzed.

CHAPTER II: REVIEW OF THE LITERATURE

Introduction

A high level human patient simulator (HPS) is a whole body mannequin with driving mechanical and computer software, capable of interacting and physiologically reacting like a "real" patient (Gaba & DeAnda, 1988). Simulators have gained wide acceptance as an essential teaching tool in such high-risk professions as manned space flight, commercial and military aviation, and in health care professions (Lupien, 1997). The use of high-fidelity patient simulators for training healthcare professionals has increased rapidly in recent years. Approximately 150 simulation training centers operate internationally (Watterson, Flanagan, Donovan & Robinson, 2000). One third of the currently available simulators are in United States academic anesthesiology training programs. The remainders are in allied health programs, such as respiratory therapy, paramedic, or nursing programs (Kapur & Steadman, 1998). The rapidly growing interest in potential applications of patient simulator technology in the field of anesthesiology is evidenced by the review of the literature where potential utilization includes teaching applications, advanced training, competency testing, and research (Gaba & DeAnda, 1989; Chopra, et al, 1994).

Theory-Practice Gap

Simulators have a wide range of teaching applications. As illustrated by Andrews and Jones (1996), over the past 15 years, the ‘theory-practice’ gap has been a recurrent theme in nurse education literature. A key component of nursing practice, to include nurse anesthesia, is problem solving or critical thinking. Techniques of developing learner proficiency in problem-solving and decision making is crucial, especially among the novice nurse anesthetist whose lack of clinical competency could lead to detrimental patient injury. Of particular significance is the cognitive perspective of learning, which emphasizes the complexity of the learning process, to include memory, learning, decision-making, and performance (Mines & Kitchener, 1986). The educational shift from learning to thinking is a shift in theories of how to teach. In many nurse anesthesia programs the dominant didactic theory of knowledge, learning, and literacy, where the student is taught *what* to think, is combined with the critical theory, where the student is taught *how to think*. *This method may leave the student struggling to grasp the concepts of problem solving with processes taught in didactic sessions with practices being gained during clinical placement.* The nurse anesthesia student should ideally integrate the concepts of critical thinking and problem solving in a controlled setting prior to entering the clinical arena.

The Role of the Human Patient Simulator in Nurse Anesthesia Education

The HPS affords the student this opportunity and has been shown to aid in bridging the gap between acquired knowledge and theory to the clinical application in the health care setting. The majority of the literature defines the role of the HPS as an integral component to experiential learning, whereby critical thinking skills are implemented into actual practice of clinical intervention (Good, 1997). As described by Monti, Wren, Haas, and Lupien (1998), the HPS at the Medical College of Georgia is the first simulator wholly owned and contained within a nurse

anesthesia program and a school of nursing. The purpose of their article was to “present the theoretical background for learning with simulation and describe the uses of simulation in nursing anesthesia, graduate, and undergraduate education at the Medical College of Georgia.” (p. 60). The concepts of declarative and procedural knowledge are discussed in relation to the importance of the student not only identifying what is wrong, but knowing what to do, and having the functional capacity to know how to do it.

The HPS is used to teach basic physiology and pathophysiology courses as well. Students receive didactic classroom instruction followed by reinforcement of theory and concepts as shown with the HPS. Basic and advanced principles of anesthesia courses are also provided in a 12-week series of biweekly sessions, with the student registered nurse anesthetist administering 20-30 simulated anesthesia inductions prior to their first actual operating room experience (Monti et al, 1998). As part of their learning experience, the students practice technical skills such as intubation, managing the difficult airway, regional anesthesia blocks, and management of critical events in the operating room. The training sessions become progressively more complex, with a final test to evaluate student’s decision-making capabilities and technical skills.

Clinical advantages and disadvantages were also presented. Potential uses include teaching, research, and student and instructor evaluation. Advantages of the HPS included real world reproducibility, exposure to infrequently occurring episodes, presentation of difficult-to-grasp concepts and adverse affects, and reinforcement of classroom instruction. Disadvantages included cost, faculty workload, limited group sizes, and the lack of published reports of efficacy.

It has been shown that computer interactive programs can enhance the assimilation and retention of knowledge (Foster, Griffith, & White, 1993). According to Good (1992), the role of high fidelity simulators in teaching new anesthesia residents resulted in better clinical evaluation

scores (in theater assessments) than the lecture-based group for the first three months.

Theoretical knowledge was similar. The simulator is a means of learning task-based subjects which can only be described and not practiced in a lecture format.

Fallacaro and Crosby (1998) also support the use of simulator experiences for the teaching of anesthesia students in managing critical events. Surveys were sent to 135 Certified Registered Nurse Anesthetists (CRNAs), with a 51% response rate. The respondents were asked to indicate how often they experienced certain pathophysiological events, and how important the respondent perceived it to be for the CRNA graduate students to experience the same event through simulator education. The survey revealed the use of the simulator experiences for critical events was found to be the most recommended curricular change by CRNA respondents.

Butters (1996) recognizes the need to explore the use of the HPS as an alternative mode of education, which would provide opportunities for students to develop competence in technical skills before using them on real patients. He questions the standard of care being provided by health care practitioners in training. Though experiential learning has been the basis for equipping students with the professional knowledge and skills needed in their careers, it raises significant medico-legal issues. The findings discussed in this paper hold several implications for educators and administrators. First, faculty has a duty to maintain their knowledge bases and skill levels in accordance with nationally recognized standards in their professions in order to adequately teach and provide patient care. Second, faculty has a duty to maintain an appropriate level of supervision during the provision of care.

These goals can be particularly difficult to attain in the field of anesthesia. As pointed out by Gaiser (2000), while demonstrating airway management techniques on live patients in the operating room or emergency room seems ideal, this technique is not beneficial for the patient or

the student. The novice places patients at risk for harm. Even with close supervision, the possibility of dental trauma, aspiration, and bruised or lacerated soft tissue remains real. Similarly, the student may be concerned about harming the patient and this stress interferes with the learning process. In addition, the time constraint imposed by oxygen saturation or delaying the start of a surgical case adds more stress to the student and limits the opportunity for instruction and criticism.

Human Error in Anesthesia Practice

Anesthesia has become safer through advances in pharmacology, understanding of physiology, improved monitoring techniques, and professional commitment to practice standards, yet human error continues to play a key role in the majority of anesthesia accidents and malpractice claims (Gaba, 1989). The ultimate goal is to improve the ability of anesthetists to respond optimally to whatever events may occur during patient care. Not only are simulators an effective initial teaching tool for the novice anesthesia provider, but they provide additional strategies for enhancing and improving continuing education and training of seasoned, practicing anesthesia providers. Anyone working in acute specialties such as anesthesia will have concerns about their ability to perform well in a difficult or life threatening situation, especially when serious perioperative problems typically arise in only 3-5% of cases (Forrest, Calahan, & Rehder, 1990). Teams responding to cardiac arrest or trauma calls can function efficiently or poorly together depending on a number of factors: knowledge, experience, team interaction, and leadership only to name a few. Scenarios can be constructed using a high level simulator, which allow individuals or teams to train for such crises.

David Gaba, from Stanford, California, coined the term “Anesthesia Crisis Resource Management” (ACRM) to describe this type of training for anesthetists (Howard, Gaba, Fish, &

Yang, 1992). An anesthetist is placed in the “hot seat” and their performance is assessed. The ACRM course includes brief didactic sessions, but is primarily made up of a set (lasting several hours) of highly realistic simulation scenarios, each followed by a detailed debriefing session, which includes reviewing videotapes of the simulation session. The course addresses medical and technical issues relevant to the scenarios. It concentrates on basic generic principles of anesthesia crisis management: leadership, teamwork, distribution of workload, communication, use of all available information and resources, and the constant reevaluation of the clinical situation. The syllabus for this curriculum has since been published as a textbook (Gaba, Fish, & Howard, 1994).

Techniques are needed to assess the anesthetists’ performance when responding to critical events. Chopra and colleagues (1994) have studied the effects of simulator training on clinical performance. Technical performance in simulations of malignant hyperthermia (MH) and anaphylaxis for anesthesia providers was observed, but only a single rater was used. Performance was improved (time in response, precision in following guidelines) in the group that had been trained in the test subject on the simulator.

The decision to incorporate clinical simulation into training programs will ultimately be based on how these devices can be used to meet the educational needs of anesthesia providers. Gaba et al. (1994) determined the anesthesia providers’ technical and behavioral performance in crisis settings can be scored reliably by faculty raters. The ability to reproduce similar scenarios using clinical simulation provided an evaluation technique to measure performance of “teams” of providers in similar crisis settings. Raters scored the videotapes of 14 different teams, which were managing two scenarios: malignant hyperthermia (MH) and cardiac arrest. Technical performance and crisis management behaviors were rated. Technical ratings of 12 crisis

management behaviors were made using a five-point ordinal scale. Several statistical assessments of inter-rater variability were applied. Team performance was found to vary and correlations among faculty members were better for technical markers than for behavioral markers of performance. Technical ratings were high for most teams in both scenarios. Ratings of crisis management behavior varied, with some teams of experienced anesthesia providers rating as minimally acceptable to poor.

Holzman and colleagues identified the usefulness of conducting crisis management training for experienced anesthesia providers in the wake of ever changing technological advancements, the introduction of increasingly potent, shorter-acting drugs, increasingly complex medical patients, and advances in surgical techniques (1995). Using ACRM principles, 68 anesthesiologists and four nurse anesthetists participated in a training course held over a two-month period. Simulator scenarios included overdose of inhalation anesthetic, oxygen source failure, cardiac arrest, malignant hypothermia, tension pneumothorax, and complete power failure. The potential benefit of the course for anesthesia providers to practice anesthesia more safely in a controlled exercise environment was rated highly by both groups.

Limitations of Anesthesia Providers

The study by Schwid and O'Donnell (1992) represents an important contribution to our understanding of the limits of performance of anesthesia practitioners. The authors developed a screen-only anesthesia simulator, allowing presentation of the same events to multiple subjects. They tested the response of 30 anesthesiologists to the same case scenarios, some of which involved serious and catastrophic events. The results were sobering with two residents seriously mishandling a simulated esophageal intubation. Less than half the anesthesiologists achieved the "correct" management of events involving myocardial ischemia, anaphylaxis, or cardiac arrest.

Suboptimal and erroneous management was common and included: failure to treat severe hypotension and tachycardia; inability to use vasoactive infusions within typical dosage ranges; and failure to monitor blood pressure adequately. In managing the cardiac arrest, no one followed current Advanced Cardiac Life Support (ACLS) resuscitation protocols unless they had received ACLS training in the previous two years. Schwid and O'Donnell acknowledged the computer-screen-based simulation is not the real operating room (OR), and so it is impossible to know whether these subjects would have performed as poorly in real life as in this study. Nonetheless, the results presented are, in general, quite consistent with those described in studies by Gaba and DeAnda (1989)(DeAnda & Gaba 1990, 1991). The problem in several cases was the failure to reevaluate a situation to realize that the initial interpretations were wrong and the therapy based on these assumptions was failing to protect the patient from catastrophe. This cognitive failure to revise a plan in face of contradictory evidence is termed a "fixation error."(Svenson & Maule,1993)

Fixation errors are probably due to fundamental aspects of human cognitive psychology in dynamic and complex work environments. These types of errors appear to occur because of limitations in our ability to deal with dynamic situations in which the available cues incompletely identify the cause (Svenson & Maule, 1993). One of the most active fields of educational research in recent years has been the investigation of problem solving and decision-making performance. Recent research has increasingly focused on problems with various occupations such as medicine (Patel, Groen, & Arocha, 1990). The anesthesia provider typically works in a stressful environment; one which includes physical stressors of crowding and noise, personal state stressors of irritability and sleeplessness, and task related stressors of time pressure and performance anxiety (Shanteau & Dino, as cited in Svenson & Maule, 1993). Anxiety and stress

has been linked to a reduction in working memory capacity and selective attention (i.e., fixation). Conditions that constrict or interfere with information processing promote the use of simpler strategies in forming judgments. Conditions such as distractions, task complexity, emotional arousal, and information overload can lead to judgments less likely to consider individual details and their complex relationships, and instead use judgmental guidance to simplify the cognitive task (Svenson & Maule, 1993).

Stress and Cognitive Performance

It is argued that cognitive functioning in general, including the decision-making process, deteriorates under stress. An important environmental factor that increases the feeling of psychological stress is time. Time stress is common in many settings, particularly in situations in which important and complex decisions must be reached, as in aviation and medicine (Svenson & Maule, 1993).

A key factor in catastrophes is the pressure to produce. Gaba (1988) refers to the anesthesia providers' temptation to cut corners due to production pressures. New safety technology has sometimes led to growth of production rather than to safety. Advanced monitoring, such as pulse oximetry and capnography, could create similar pressures to perform anesthetics or utilize techniques that previously were considered hazardous.

In a study performed by Byrne, Sellen, and Jones (1998), the performance of 10 trainee anesthetists was measured during a single simulated complex critical incident. The critical incident was designed to be stressful and contained, in sequence, episodes of hypotension, arrhythmia, and bronchospasm. Errors in the recording on the anesthetic chart were used as a measure of mental workload and performance. Chart recording errors increased markedly during the critical incident ($P<0.01$) and decreased when the "patient" stabilized. Gaba and Lee (1990)

studied the effects of workload of anesthetists during real anesthetic cases by asking them to add together two numbers on the screen of a computer and record the sum at regular set intervals. The study showed that in times of stress, the anesthetists took longer to add the numbers or failed to respond at all.

As mentioned, the anesthesia provider must perform many necessary tasks concurrent with making complex decisions. In addition, the anesthetist is responsible for adequate airway management, which is the foundation on which anesthesiology and resuscitation are built. Consequently, it is essential that all anesthesia providers acquire proficiency in this life-saving skill. Gaiser (2000) stresses the importance of teaching airway anatomy, airway evaluation, and airway management techniques prior to anesthesia residents entering the clinical arena. The author recommends the use of patient simulators. The mannequins currently provide fairly realistic anatomy and allow for procedures such as fiberoptic intubations and cricothyrotomy. It is noted that simulator training alone is not sufficient for developing intubation skills.

Sayre, Sikles, and Mistler (1998) studied 66 emergency medical technicians (EMTs) who received 10 hours of instruction on airway management and who successfully intubated a simulated mannequin 10 times. Of the 103 intubations in the field by these EMTs, only 53 were successful, with some of the intubations requiring more than one attempt.

Cheney, Posner, and Caplan (1991) previously provided a detailed description of data collection procedures of adverse anesthetic outcomes obtained from the closed claims files of 23 United States professional liability insurance carriers. The purpose of the report is to provide an analysis of several categories of respiratory-related adverse outcomes in which recurrent themes of management error or patterns of injury could be identified. Airway trauma was sub classified as to whether it was associated with a difficult intubation. Pneumothorax was related to

performance of a regional block in 40% of the cases. The majority (89%) of airway obstruction occurred during general anesthesia as a result of upper airway occlusion. General anesthesia was the predominant anesthetic technique in cases of aspiration (98%). Bronchospasm occurred more frequently during general anesthesia with 48% of the patients having a history of asthma or chronic obstructive pulmonary disease and/or smoking. Overall, 89% of the adverse events in this report represent problems with airway management, which is the anesthesia provider's responsibility. It is apparent why the anesthesia provider should maintain his/her proficiency in airway management skills.

Human Patient Simulators and Life-saving Training

In addition, formal instruction in difficult airway management is discussed in the study by Koppel and Reed (1995) where very few anesthesia residency programs were found to offer formal instruction in difficult airway management. It is commonly taught as difficult clinical situations arise. Because these situations occur sporadically, opportunities for teaching are occasional and unpredictable. Learning based on sporadic and occasional occurrences risks incomplete and non-uniform training of residents. Only 27 percent of anesthesia residency training programs provided formal difficult airway management training. Of those programs, which do offer formalized instruction; it lasts only one to two weeks. Much of this experience is limited to lecture with minimal practical exposure. The authors recommend block rotations in difficult airway management, which are devoted to hands-on experience with a variety of different methods. Methods of presenting didactic information include videotape and computer-assisted instructional programs. HPS mannequin practice complimented by patient care experiences will assist in achieving technical mastery (Ovassapian, Yelick, Dykes, & Golman, 1988).

Human Patient Simulators are proving beneficial to trauma care teams as well.

Maniscalco-Theberge and Elliot (1999) describe trauma care in the new millennium with the use of virtual reality, robotics, and other technology. These innovations have facilitated information and enhanced surgical education and clinical trauma care.

The Eagle Trauma Patient Simulator (MedSim, USA, Binghamton, NY) allows anesthetic and drug manipulation of the mannequin with programmed scenario responses for different actions. The monitors respond to the interventions as if the mannequin were alive. The Eagle Trauma Simulator is interactive; during examination the pupils react, the arms respond to stimuli, and the monitors physiologically respond to trauma procedures such as placement of chest tubes, needle decompression, and central line placements.

The management of multiple injured trauma patients is a skill requiring broad knowledge, sound judgment, and leadership capabilities. A study conducted by Gilbart and associates (2000) evaluated the effectiveness of a trauma patient simulator as a teaching tool for senior medical students. Outcome measures were students' trauma objective structured clinical examination (OSCE) scores. The two courses were fundamentally based on teaching students the standard rules and protocols for clinically managing patients in the preliminary stages of a trauma scenario. The skills taught in both courses improved student performance. No significant difference was found between the two teaching group performances (trauma simulator and seminar) on the trauma OSCE. There was a tendency toward improvement in the trauma simulator-trained group, but it did not reach statistical significance. Despite this result, significantly more students in the trauma simulator-trained group felt the course increased their clinical competence. Students expressed a preference for training with the trauma simulator, though the traumasimulator was not shown to improve student performance over the seminar.

training. It seems that the simulator if available, should be utilized for trauma teaching, as student enthusiasm and confidence with this instructional tool has been well documented.

Human Patient Simulators and Research

Research studies utilizing the HPS are ongoing. Bedforth and Hardman (1999) compared the accuracy and reliability of a validated, physiological simulator to six intensive care specialists in predicting changes in arterial oxygen tension, arterial carbon dioxide tension, and pH following mechanical ventilation adjustments. The simulator was found to be more accurate and consistent than physicians in predicting the change in oxygenation and pH. The simulator systems can also allow for testing of new equipment and performing of advanced technical procedures without causing harm to real patients.

Research insight into human behavior during stress is just one aspect of the value of observational simulator studies. Erler and Rudman (1993) studied the effects of a simulated critical care experience on nursing students' state of anxiety in the critical care unit. The focus of the patient simulator was to familiarize nursing students with psychomotor skills commonly needed in the highly technological environment and to provide a risk-free environment for successful skill mastery and feedback. The study results indicate that attending an ICU simulation and familiarity with critical care psychomotor skills did not result in a reduction in clinical anxiety. However, one allotted clinical day for campus simulation may not afford students the time and experience to feel comfortable in the ICU. According to Benner (1984), nursing students enter a new clinical arena as novices, and it is only with repeated clinical experiences that one gains confidence and competence.

Summary of the Literature

The current body of knowledge supports the utilization of the HPS in the education of health care professionals. Results of current studies reveal the rapidly growing interest in potential applications in the field of anesthesiology. Such applications include training, competency testing, team effectiveness skills, and research.

The HPS provides an avenue for both the instructors and students to apply knowledge and clinical skills in a high-acuity situation or to conduct low-frequency clinical scenarios, both in a realistic environment, without putting themselves or an actual patient at risk.

The major advantage of the HPS for training is the ability to present known events (both catastrophic and noncatastrophic) repeatedly, allowing students to become proficient in recognizing and effectively treating the adverse event.

The chief disadvantage of the HPS is that it cannot simulate the real clinical setting, which ultimately affects the anesthesia practitioner's behavior, critical thinking skills and overall performance.

However, despite current research, training on a HPS cannot ultimately predict a student's performance in the actual clinical arena. Despite the growth in the number and quality of anesthesia providers, human error remains the major cause of anesthesia-related morbidity and mortality (Gaba, 1989). The HPS has been shown, however, to reduce fixation errors in the simulated setting.

Research must support the effectiveness of the HPS in producing high quality, safe, and competent CRNAs. The HPS can be utilized to develop the student characteristics needed for success in the clinical portion of their graduate education and future careers as CRNAs. Clayton, Lypek, and Connelly (2000) identified problem areas in previous nurse anesthesia students who failed the clinical portion of graduate school. Such areas included the inability to

handle stress or lack of hardiness, inability to transfer theory into practice, lack of critical thinking skills, and lack of interpersonal and team skills. All of these areas can be addressed in the HPS environment.

However, due to the substantial financial investment required to support a simulation facility and the lack of data supporting improved clinical practice, the capabilities of the HPS must be supported through further research of the impact of simulation on the cognition of the student. The likelihood of quality clinical performance is enhanced with improved cognition and knowledge retention.

Conclusion

High fidelity HPS systems are expensive to purchase and operate. Initial purchase and set-up costs for a center are estimated to be from \$200,000 to \$300,000 depending on the simulator chosen, the availability of existing medical equipment and supplies, and the audio/video equipment (Howard, Gaba, & Fish, 1992). Space, which is at a premium in most hospitals and universities, can also be very expensive. Additional operating expenses include equipment upgrades, utility gases, props, and personnel costs. In many centers, a technician is hired to be the manager of the center's resources. This individual must combine technical expertise, people skills, and hopefully have a medical background (CAE electronics, 1996).

Consequently, it is important that the perceived benefits of this type of training are evaluated and proven if resources are to be allocated to this type of education. The educational benefits may relate to the various ways in which the simulator is utilized. As demonstrated, students consistently report increased self-esteem and confidence in their own abilities after participating in a simulator-training course (O'Donnell, 1998). Crisis or team training might improve clinical performance in stressful situations (Gaba & Lee, 1990). Using the simulator in

small group teachings has been shown to enhance the assimilation and retention of knowledge (Foster et al, 1993; Schwid et al, 1997).

The use of the HPS and videotaped sessions provide the ability to analyze and reflect on one's own clinical performance. Reflection is a method of learning and teaching professional maturity through a critical analysis of experience (Durgahee, 1996). Problem-based learning is an approach designed to develop analytical, critical thinking skills by a process of logical deduction. Refining these critical skills is of utmost importance to the anesthesia provider. Improving techniques of problem-based learning and training will allow anesthesia providers to broaden their knowledge and skill armament and increase the likelihood of responding appropriately to any given situation. This is being carried out within the framework of simulated clinical situations with the use of the HPS. Problem-based learning with the HPS integrates formal theory with real situations; however, clarifying the decision-making processes employed in the classroom cannot provide an accurate indication of how a student will perform in reality, nor can the ultimate reliability of the simulator in motivating students to learn and promoting independent critical thinking demonstrate improved clinical practice.

The value of simulators as an adjunct to clinical teaching and their effects on clinical performance and competency continues to be a topic of ongoing research and evaluation. It is recognized that education strategies must reflect the content and teaching methods that best match the learning objectives: to produce motivated, safe, and skilled nurse anesthetists who are able to provide quality patient care within the pressures of today's medical delivery system. Skill building requires interactive strategies rather than mere information dissemination (Ockene & Zapka, 2000) and computerized human patient simulators can assist in providing the training necessary to meet these objectives.

CHAPTER III: METHODOLOGY

Research Design and Procedures

This study evaluated the effectiveness of a computer-based human patient simulator (HPS) as a teaching tool for first-year student registered nurse anesthetists (SRNA). The study used a quasi-experimental, two-group, pretest-post-test research design. This design was selected to compare the amount of knowledge acquired among SRNAs during an anesthesia pharmacology course of instruction provided in both a traditional classroom setting and the HPS laboratory.

Burns and Grove (1997) identify the quasi-experimental design as an alternative approach for the assessment of causality in situations where experimental controls are not practical. This design is meant to control as many threats to validity as possible in a situation where true experimental components are lacking, such as random sampling, control groups, and manipulation of the treatment.

The study was conducted using an anesthesia simulator to evaluate its effectiveness as a teaching tool for anesthesia pharmacology. Each of twelve first year nurse anesthesia students was asked to participate in two teaching sessions. All participants ($n=12$) completed a 20-item pre-test before attending their randomly assigned teaching session, being either the classroom or HPS lab. Participants were not aware of the course content prior to completing the pretest. The block of instruction included stated objectives for intravenous induction agents. (Appendix A) The quasi-experimental, pretest-post-test design is limited by several uncontrollable threats to validity. Events such as statistical regression, maturation processes, and changes in instrumentation may occur between the pretest and post-test and may, therefore, alter the post-test results.

This study was performed with the participation of the first year nurse anesthesia student class at the Uniformed Services University of the Health Sciences located in Bethesda, Maryland on 18 May during the 2001-2002 academic year. Each of the twelve SRNAs was asked to participate in the anesthesia pharmacology course.

The students acquired knowledge of the pharmacology of induction agents in anesthesia. Each teaching session was limited to six students. To minimize instructor variability, the two selected instructors prepared a mutual lesson plan and taught identical anesthesia course content for both the classroom lecture and the HPS teaching session (Appendix A).

Both lecture and HPS pharmacology sessions focused on five induction agents: Etomidate, ketamine, methohexitol, propofol, and thiopental. Physical characteristics, pharmacokinetics, pharmacodynamics, indications, dosage and administration, and precautions for each medication were discussed (Appendix A). The students were able to anticipate and identify what medication has been administered to a patient based on its physiological effects.

The two courses differed in that SRNAs in the lecture group discussed pharmacological aspects and clinical implications of induction agents. In contrast, SRNAs in the HPS group actually performed an anesthetic induction on the mannequin by actually administering induction agents and witnessing the physiological responses on the patient monitor. Case scenarios utilizing the appropriate induction agents were addressed in both teaching sessions. Students were given time in both teaching sessions to ask questions, clarify concepts, and provide feedback.

This pilot study used an anesthesia simulator to evaluate its effectiveness as a teaching tool in anesthesia pharmacology. The CAE Electronics Patient Simulator System is a life-sized mannequin with an associated computer software system. The operator had the capability of

simulating a variety of clinical scenarios with the mannequin. The mannequin was oriented on a stretcher in a room organized to mimic an operating room environment.

The simulator hardware and software provides input to actual clinical monitors. The HPS physiological program provided the instructor with numerous cardiac and vascular parameters, which could be altered (Table 1). The HPS was also used to depict pulmonary physiology (Table 2). By altering the HPS's respiratory drive or ischemic index, the effects of powerful induction agents on patients with fragile cardiovascular and respiratory systems were simulated. The mannequin also allowed for a number of clinical interventions and manipulations, including mask ventilation, endotracheal intubation, mechanical ventilation, infusion of intravenous (IV) fluids, and specifically, the administering of IV induction agents. The simulator center also included a standard Ohmeda anesthesia machine and monitoring equipment needed to provide anesthetic care based on current practice standards.

The SRNA participants completed a twenty-item pretest as a written assessment of their base-line knowledge related to induction agents in anesthesia prior to participating in the randomly-assigned teaching sessions (See Appendix B). Six SRNAs received a 1.5 hr lecture in the traditional classroom setting, while simultaneously, the remaining six SRNAs received the 1.5-hr lecture material utilizing the HPS laboratory. The teaching session was incorporated during a seven day Anesthesia Pharmacology course in May 2001. All SRNA participants completed a 20-question post-test immediately following the 1.5hr block of instruction on induction agents. (Appendix B) Part I of the course evaluation was also distributed and completed by each participant. (Appendix C) Participants were allowed to break and return at a specified time. The students then attended the unassigned, opposite teaching session. A final course evaluation was completed by all participants at the completion of the course instruction.

The evaluation tool assessed which teaching session the SRNA preferred, Likert-type scale ranked questions, and open-ended items to explore the student's expectations, course strengths and weaknesses, and recommendations for future courses (Appendix D).

Table 1.**HPS Cardiovascular Parameters**

Aortic valve resistance
Baroreceptor sensitivity
Central venous pressure
Heart rate
Heart sounds/murmurs
Ischemic index sensitivity
Mitral valve resistance factor
Pulmonary artery catheter position
Pulmonary valve resistance factor
Pulmonary vascular resistance
Systemic vascular resistance
Venous capacitance
Left and right ventricular contractility

Table 2.**HPS Respiratory Parameters**

Breath sounds
Left and right bronchial resistance
Chest wall compliance
Tidal volume
Respiratory rate
Functional residual capacity
I:E ratio
Left and right intrapleural volume/compliance
Oxygen consumption
pH shift
PetCo ₂ -PaC ₀₂ factor
Respiratory quotient
Shunt fraction
Laryngospasm

Sample

The research study consisted of a convenience sample of twelve first-year SRNAs attending the Uniformed Services University of the Health Sciences, Graduate School of Nursing. All students successfully completed 11 months of didactic instruction in the Basic Sciences and Anesthesia Principles prior to this study. All students had prior exposure to the HPS laboratory. Participants were approached in person by the primary investigator and were asked to participate in the study aimed at evaluating the effectiveness of the HPS as a teaching tool in nurse anesthesia education. Simple random sampling was used to determine which students would attend the classroom instruction or the HPS instruction. Students were randomly assigned by drawing a slip of paper from a container indicating the method of instruction- either “simulator” or “classroom” until the desired sample size was reached. Sample size for this pilot study was determined based on a power analysis of .80, a significance level of .05, and a medium to large effect.

Measurement

Outcome measures included the completion of a twenty-item post-test (Appendix B). The written post-test addressed pharmacological components and clinical implications of anesthetic induction agents. The dependent variable, a written post-test examination, was scored and measured. Comparison of the pre and post-examination scores in each teaching group was completed using the paired t-test to determine the significance of improvement in scoring within each group. An independent t-test compared the mean post-examination scores between the teaching groups to determine the difference in the amount of learning that occurred.

Test questions required the students to identify the appropriate drug, interpret clinical data, and define key physiologic features of common induction agents. Written examination problems were concise and focused on critical elements of anesthesia pharmacology. Test items were developed according to the Computer Adaptive Technologies, Inc. (CAT) recommendations. The CAT guide facilitates the process of developing and writing items for multiple-choice examinations and aids the writer in creating valid, accurate, and reliable test items. The focus on critical pharmacological concepts and a broad sampling of problems provided a foundation for the content validity. In addition, validity of the pre-test and post-test was determined by subject matter experts (SME) in the field of anesthesia and anesthesia simulator training. Written standards of care of anesthesia practice were also used to determine the essential knowledge to be evaluated. Poorly scored test items were evaluated for reliability and validity by the Uniformed Services University Test Scoring Service Center prior to repeated implementation.

Subjective evaluations of the study by the participants were measured using a Likert scale and an open-ended question format.

Protection of Human Rights

The rights of the participants were protected based on the guidelines set forth by the Institutional Review Board (IRB) at the Uniformed Services University of the Health Sciences. Participants will be fully informed regarding the purpose and methodology of the study. All subjects were asked to sign an informed consent form prior to the conduction of the experiment (See Appendix E). Participants were able to withdraw from the study at any time without any risk of retribution. There was no risk to the participant of physical or mental harm. All data collected was kept confidential and was maintained in the Silver Spring office of Dr. Eugene

Levine, only accessible to the researcher, committee chair and research committee members.

There were no videotaped sessions in the HPS laboratory during the study.

Data Analysis

Correlational data from the pre-test and post-test examination scores related to the teaching method were analyzed. Knowledge retention was measured by collecting pre and post-test examination scores. Using a paired t-test and an alpha level of $p=.05$, comparison of the two assessments determined significant improvement in examination scores after both pharmacology teaching sessions. The independent t-test was performed to determine if there was a statistically significant difference in the amount of learning between the two teaching groups.

Demographics were not collected to maintain anonymity among the small sample size. The Statistical Package for the Social Sciences (SPSS) 10.0 was used for data organization. Subjective responses of the participants were also analyzed.

Summary

Although simulation exercises provide exciting and unique educational opportunities in anesthesia, little data exist regarding impacts on measurable outcomes of this expensive and high fidelity technology. A quasi-experimental design is the most appropriate method to conduct a pilot study to help determine the effectiveness of the Human Patient Simulator as a teaching tool in nurse anesthesia education. This design will have limitations; however, the limitations will not undermine the value of this study for future research.

CHAPTER IV: DATA ANALYSIS

Introduction

The purpose of this study was to evaluate whether experiential-learning with the Human Patient Simulator (HPS) enhanced knowledge retention of anesthesia pharmacology concepts among Nurse Anesthesia students, as evidenced by an improved performance on a twenty-item written post-examination. This single question was reexamined and addressed. Participants' responses to the anesthesia pharmacology course evaluation were also analyzed.

Analysis of Data

One pretest was administered to twelve first year Nurse Anesthesia students participating in the study prior to attending their assigned teaching sessions on induction agents. Of the 12 participants enrolled in the study, 6 attended the HPS lab for instruction while 6 attended a classroom lecture. The exam was administered in a monitored and quiet setting. The pretest score served as a control for each student (Table 3). There was not a significant difference in pretest scores among the two groups, indicating common baseline knowledge of the student participants. The participants assigned to the HPS lab scored slightly lower on the pretest than those assigned to the classroom. (M simulator – 8.8; M classroom – 9.66). The median score, not being affected by extreme scores or outliers in the data, was 40.0 percent and 47.5 percent for the simulator group and classroom group respectively.

Table 3.**Pretest Scores: The Frequency of Correct Responses**

Teaching Session Responses	Number of Subjects	%Correct
Simulator	6	44.0
Classroom	6	48.3

Random selection was the only acceptable way of maximizing the probability of equivalence between the two student groups ($n=6$). Despite the small randomized sample size, there was knowledge equivalence between both groups, with the baseline pretest scores showing no statistically significant difference ($t=.781$, $p=.858$). The two-group pretest, post-test design was utilized. Serving as the control group, six students attended the teaching session in the traditional classroom setting. Simultaneously, while serving as the experimental group, six students attended the teaching session utilizing the HPS lab. Both groups received the same course content on anesthesia induction agents (See Appendix A). Immediately after the 1.5- hour sessions, all students returned to a monitored classroom and completed a 20-item post-examination (Table 4) and Part I of the course evaluation. (Table 7).

Participants in the HPS lab scored higher on their post-examination tests in comparison to the participants in the traditional classroom setting ($M_{\text{simulator}} = 15$; $M_{\text{classroom}} = 13.2$). The median score, not being affected by extreme scores or outliers in the data, was 73.0 percent and 64.0

percent for the simulator group and classroom group respectively. This correlates to a 66 percent improvement in test scores among the HPS lab group compared to a 33 percent improvement in test scores among the traditional classroom group. There was statistically significant improvements in learning within each teaching group (simulator $t = 4.66$ $p = .005$, classroom $t = 4.84$ $p = .005$).

Table 4.

Post-test Scores: The Frequency of Correct Responses

Teaching Session	Number of Subjects	%Correct Responses	%
Improvement			
Simulator	6	73	66%
Classroom	6	64	33%

After completion of the post-examination test, students attended lunch and returned for a repeated 1.5hr lecture in the alternate teaching session. A final course evaluation was completed after the final teaching session. (Table 7)

Table 5.**Statistical Analysis of Pretest and Post-test scores by Teaching Site:**

Teaching Site	Simulator	Classroom
Sample size (n)	6	6
Pretest Mean score	8.83	9.66
Post-test Mean score	14.667	12.833
Standard Deviation (SD)		
Pre-test	1.722	1.966
Post-test	2.503	2.137
Minimum score (pretest/post-test)	7.0/11.0	7.0/11.0
Maximum score (pretest/post-test)	11.0/17.0	13.0/16.0
Level of Significance (2-tailed)	0.0055	0.0047

To determine the effectiveness of simulation versus traditional classroom teaching, a comparison was made between the mean post-examination scores of the two teaching groups to determine the absolute difference in learning. With at least 6 subjects in each group, a .896 power detected a large significant difference at .05 based upon the mean difference of 4.5 and a standard deviation of 2.71. Greater improvement was noted in the HPS group, with a mean score of 4.5 higher than the lecture group, approaching clinical significance. ($t= 1.89$, $p= .088$).

Table 6.**Statistical Analysis of Pretest and Post-test scores between Teaching Sites:**

Teaching Site	Simulator	Classroom
Sample size (n)	6	6
Pretest Mean score	44.1667	48.3333
Post-test Mean score	73.3333	64.1667
Standard Deviation (SD)		
Pre-test	8.61201	9.83192
Post-test	12.51666	10.68488
Difference in Scores	29.1667	15.8333
Absolute Difference	5.8333	3.1667

Student Evaluation of the Course

At the end of the course students completed their evaluations anonymously.

Questionnaires were distributed to twelve nurse anesthesia students and were completed after the post-examination. Students were advised to return the completed questionnaire prior to leaving the classroom. Twelve completed questionnaires were returned, corresponding to a 100% return rate.

The evaluation tool included Likert-type questions and additional open-ended items, which explored expectations, course strengths and weaknesses, and recommendations for future courses. Part one of the questionnaire asked each participant to indicate which teaching session they attended, followed by Likert scale questions (Table 7). The Likert scale is the most commonly used of the scaling techniques, with a value of 1 placed on the most negative response and a value of 5 placed on the most positive response (Burns & Grove, 1990). In the first two questions, the participants were asked to rate the content of the teaching session, whether the course objectives were met and whether the lecture was presented in a well-organized manner. Thirty three percent of the students in the simulator group felt that the course objectives were not met, whereas 100 percent of the students attending the classroom session agreed the course objectives were met. Overall, all students felt the lecture material was presented in a well-organized manner. However, two participants in the simulator group chose the response of “neutral”. When asked to rate the effectiveness of the instructor, one of the twelve participants responded negatively.

Two open-ended questions elicited information regarding the strengths and weaknesses of the teaching session. Space was also provided for any additional comments about the course instructors. General strengths reported among the simulator group included the ability to “visualize direct effects of drugs”, enjoying the “student interaction”, and the use of “hands-on” practical effects of inductions agents. Weaknesses included the lack of overall organization and control of the simulator teaching setting.

Responses of the participants in the traditional classroom setting listed instructor’s knowledge, expertise, and sharing of his career experiences as strengths of the teaching session.

Weaknesses of the classroom session included not being provided with hand-outs prior to the lecture and the inability to conceptualize hemodynamic responses to various induction agents.

A final questionnaire was completed at the end of the overall course (See Appendix D). Participants were asked to indicate which method of teaching they preferred and which teaching session helped them best understand the pharmacology concepts of anesthesia induction agents (Table 7). Participants were also asked to re-evaluate the instructors of each session. The final question asked the student to rate their overall impression of the pharmacology course. Eleven of the twelve students selected the simulator (HPS Lab) as the preferred method of learning; however, only nine of the twelve felt the simulator best illustrated pharmacology concepts of induction agents. The overall impression of the pharmacology course on Anesthesia induction agents was rated “good” by 50%, “excellent” by 42%, and satisfactory by 8% of the participants.

Table 7. Student Questionnaire Responses

	Method of Teaching Preferred		
	Simulator	Classroom	Total
Teaching Environment			
Simulator responses	5	1	6
Classroom responses	6		6
Total	11	1	12
Pharmacology Concepts best- understood			
	Simulator	Classroom	Total

Teaching Environment			
Simulator responses	5	1	6
Classroom responses	4	2	6
Total	9	3	12

	Course Objectives Met			Total
	Disagree	Agree	Strongly Agree	
Teaching Environment				
Simulator responses	2	2	2	6
Classroom responses		3	3	6
Total	2	5	5	12

	Overall Impression of Course			Total
	Satisfactory	Good	Excellent	
Teaching Environment				
Simulator responses	1	3	2	6
Classroom responses		3	3	6
Total	1	6	5	12

The data were further analyzed to determine if instructor variability played a role in the participants' knowledge retention and satisfaction with the course. Group statistics and cross tabulations were conducted, with equal variances assumed, which revealed no statistical significance between the two instructors (Table 8). It is interesting to note that the classroom instructor had more favorable outcomes on the student evaluations; however, higher post-examination scores were found among the simulator group. This may suggest the method of the "style" of teaching is more important than the teaching tool.

Table 8.**Student Evaluations of Course Instructors.**

	Lecturer	N	Mean	Level of Significance (< .05)
Lecture well-organized	Simulator	6	4.0	.448
	Classroom	6	4.5	
Effective Teaching Method	Simulator	6	3.6667	.105
	Classroom	6	4.1667	
Well-prepared & knowledgeable	Simulator	6	4.1667	.111
	Classroom	6	4.8333	

CHAPTER V: SUMMARY

Offering significant degrees of training for various health professionals, the Human Patient Simulator (HPS) is becoming an exciting and attractive focal point of the curriculums in many disciplines of medical school education. The HPS has a wide range of unique features that are unsurpassed as educational tools in developing an anesthesia provider's clinical skills.

A key component of nurse anesthesia is critical thinking- choosing and implementing effective solutions to problems faced in clinical practice. Techniques of developing clinical proficiency in nursing anesthesia are crucial and should occupy a substantial portion of the nurse anesthesia curricula. The gap, which exists between theoretical knowledge and clinical practice, has suggested recent changes in the content of nursing programs (Monti et al, 1998).

The integration of the HPS with the traditional lecture series, in combination with a quality clinical learning environment, can aid in developing competent nurse anesthetists. This becomes especially important to the CRNA working in environments lacking resources and personnel, as they must rely heavily on their own knowledge and experience, which is often derived from their professional educational preparation.

The issue of transfer is paramount to the education process, where didactic theoretical knowledge is applied in clinical practice, yet there is still considerable controversy in the

literature regarding its existence and whether training with the HPS actually bridges this gap. It is known that learning through simulation provides the opportunity to make repeated mistakes without harming an “actual” patient, but the question still remains- Does simulation enhance learning? Despite current research, training on an HPS cannot ultimately predict student performance in the actual clinical arena. There are, however, limited studies that have analyzed the cognition of the learner (Foster, Griffith, & White, 1993; Good, 1992)

The purpose of this study was to determine if the use of the HPS enhanced knowledge retention of anesthesia pharmacology concepts among first-year nurse anesthesia students, as evidenced by improved performance on a 20-item post-examination test.

The two teaching sessions were based on teaching students fundamental clinical concepts of anesthetic induction agents. The implementation of these two sessions was different only in that students in the HPS group managed scenarios and visualized pharmacological effects of the medications. Thus, the information taught in both sessions improved student performance. Both the simulator and classroom group examination scores significantly improved based on post-examination scores ($p= .005$). With a power of .896, a significant difference ($p= .05$) was detected between the two groups based on a mean difference of 4.5, with a greater improvement noted in the HPS teaching group. Both teaching groups improved in their performances on the examination, suggesting that the type of teaching had an equivalent influence on student performance. Overall, the results of this study suggest that the active process of learning anesthesia pharmacology concepts using the HPS may be superior to the traditional lecture method of teaching. This study also supports the fact that the HPS could be utilized as a powerful adjunct, if not the primary method, of learning anesthesia pharmacology concepts.

In addition to these significant findings, students overwhelmingly felt the HPS was an effective teaching aid. These study results are consistent with published reports of computer-based simulation models in the literature, in which these models have been purported to make learning easier and more enjoyable, thus potentially enhancing student understanding of material through increased motivation and effort (Monti et al., 1998). It seems that the HPS could be utilized for any aspect of anesthesia training, as student enthusiasm and confidence with this instructional tool has been well-documented (Gaba, 1989; Holzman, 1995).

Limitations

Limitations to this study include the Hawthorne effect, test-retest situations, sample size, characteristics, and selection. The Hawthorne effect explains subject responses may be altered by the fact that participants are aware that they are in a research study (Burns & Grove, 1990). The Hawthorne effect also implies that subjects perform better when they know they are being evaluated. This potentially alters the significance of the study's results.

The pretest and post-test with an untreated control group (classroom group) is a quasi-experimental design that is interpretable, but uncontrolled threats to validity occur primarily due to the nonequivalent control group (Burns & Grove, 1990). In this study, however, both the control group and experimental group scored equivalently on the pretest examination. The same test was administered for both the pre-test and post-test examination; therefore, subjects could remember their responses and select differently on the post-test based on memory.

The sample was one of convenience. The sample size, though small, was still able to detect significant correlation in the findings. Though the population consisted of active duty military members, the U.S. military population comprises a diverse group, yet this sample does

represent some limitation in the ability to extrapolate to the general population of nurse anesthesia students.

With the use of two instructors, and not the same instructor, providing teaching for both the simulator and the classroom course, instructor variability could not be minimized. However, the data analysis did not reveal statistical significance among the differences between instructors, based on overall student performances and evaluations (Table 8).

Recommendations

It is recommended that a longitudinal study consisting of a larger, varied sample size be obtained among the student nurse anesthesia population by requesting first-year nurse anesthesia students attending both the Uniformed Services University of the Health Sciences and Georgetown University to participate in this type of research study. A larger sample would predictably allow for a statistically significant outcome of the effectiveness of the HPS in learning. A diverse sample of both military and civilian nurse anesthesia students would allow for generalization of the research findings.

It is also recommended that the student questionnaire include inquiries regarding the HPS being a required course in the nurse anesthesia curriculum and whether this requirement would influence the applicant's decision in choosing a graduate school.

Computer-based simulation may have many uses in the education of nurse anesthetists of tomorrow. Before the capability of these systems can be realized, further research is required to determine the impact of computer-based simulation on the cognition of the learner

Due to the substantial financial investment required to support a simulation facility and the lack of data supporting improved clinical practice, the capabilities of the HPS must be supported through further research of the impact of simulation on the cognition of the student. The likelihood of quality clinical performance is enhanced with improved cognition and knowledge retention.

Learning through simulation is a vital component of virtually every medical school curriculum. Every accredited nurse anesthesia school curriculum should offer the unparalleled degree of training with the HPS as well. The HPS provides powerful lessons that nurse anesthesia students will carry with them throughout their professional lives. In order to justify the substantial financial investment, however, its necessity must be supported through further nursing research.

Appendix A- Course Objectives

Anesthesia Pharmacology- Induction Agents

Uniformed Services University
Anesthesia Pharmacology
GSN 0706

Intravenous Induction Agents

Objectives:

On completing this block of instruction, the student will be able to meet the below stated objectives for the following agents:

Methohexitol

Propofol

Thiopental

Ketamine

Etomidate

1. Identify the major mechanism of action of each intravenous induction agent.
2. Discuss the pharmacokinetic properties of each agent to include protein binding, distribution, metabolism, and excretion.
3. Describe the principal clinical uses of each agent in the anesthesia arena.

4. Identify appropriate dosing regimens for each intravenous induction agent.
5. Discuss significant side effects of each induction agent.
6. Identify the major indications and contraindications for the use of each induction agent.

Appendix B

Pre-examination/Post-examination

Pre-test/Post-test

Student Code # _____

1. **How long do refrigerated solutions of thiobarbiturates remain stable?**
 - a. 1 day
 - b. 1 week
 - c. 2 weeks***
 - d. 1 month

2. **All of the following produce an isoelectric EEG and a decrease in the CMRO₂ EXCEPT:**
 - a. Ketamine***
 - b. Thiopental
 - c. Etomidate
 - d. Propofol

3. **The rapid RECOVERY from a single bolus of Propofol is due to:**
 - a. Urinary excretion of conjugated metabolites.
 - b. Hepatic conjugation to glucuronide.***
 - c. The lack of hypnotic activity of metabolites.
 - d. Redistribution to adipose tissue. (redistribution to LEAN tissue would be correct)

4. An appropriate induction dose of propofol for a healthy adult is
 - a. 250 mg
 - b. 2-2.5 mg/kg***
 - c. 3 mg/kg
 - d. 0.3 mg/kg
5. After use of ketamine, which of the following may most effectively attenuate emergence delirium?
 - a. Propofol
 - b. Versed**
 - c. Fentanyl
 - d. Droperidol
6. Barbituric acid is formed by the combination of which two compounds?
 - a. Lactic acid and sulffa
 - b. Hydrochloric acid and a phenyl group
 - c. Sulfuric acid and a methyl radical
 - d. Malonic acid and urea***
7. Which of the following induction agents produces anesthesia by disassociating the thalamocortical system from the limbic system?
 - a. Propofol
 - b. Thiopental
 - c. Ketamine***
 - d. Etomidate
8. Myoclonus, dystonia, and tremors may occur with administration of which induction agent?
 - a. Propofol
 - b. Thiopental
 - c. Ketamine
 - d. Etomidate***
9. Which of the following induction agents decreases the incidence of post operative nausea and vomiting?
 - a. Propofol***
 - b. Thiopental
 - c. Ketamine
 - d. Etomidate
10. Which of the following induction agents causes adrenocortical suppression?
 - a. Propofol
 - b. Thiopental
 - c. Ketamine
 - d. Etomidate***

11. Which of the following induction agents is a phencyclidine derivative?

- a. Propofol
- b. Thiopental
- c. Ketamine***
- d. Etomidate

12. Which of the following statements is TRUE regarding ETOMIDATE:

- a. Etomidate has a low lipid solubility and small nonionized fraction at physiologic pH.
- b. Etomidate has minimal effects on the cardiovascular system.***
- c. Etomidate releases histamine.
- d. Etomidate increases cerebral blood flow and intracranial pressure.

13. Which of the following induction agents is rapidly metabolized by hydrolysis of the ethyl ester side chain?

- a. Propofol
- b. Thiopental
- c. Ketamine
- d. Etomidate***

14. Which of the following induction agents produces intense analgesia?

- a. Propofol
- b. Thiopental
- c. Ketamine***
- d. Etomidate

15. The pH of a 2.5% solution of thiopental is

- a. 2.5
- b. 5.5
- c. 7.5
- d. 10.5***

16. Which of the following would be beneficial as an induction agent in a patient with active bronchospasm?

- a. Propofol
- b. Thiopental
- c. Ketamine***
- d. Etomidate

17. The contents of an opened vial of propofol must be discarded within how many hours?

- a. 6 **
- b. 10
- c. 18
- d. 24

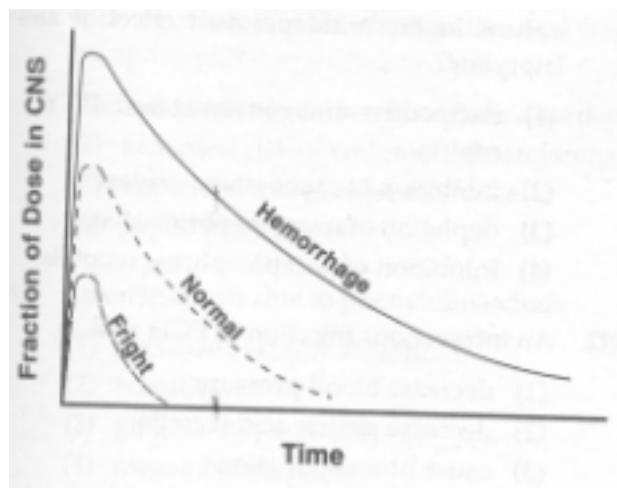
18. Which induction agent is NOT commonly used in neuroanesthesia?

- a. Ketamine***
- b. Propofol
- c. Thiopental
- d. Etomidate

19. A patient is scheduled for an elective cardioversion. A single intravenous injection of a short-acting agent is planned. Which of the following agents is most likely to cause vomiting after the procedure when used in this patient?

- a. Ketamine
- b. Thiopental
- c. Methohexitol
- d. Etomidate***

20. The figure below depicts the relative effect of thiopental in three different physiologic states. From this figure we can say:



- a. In the normal patient there is an initial high concentration followed by a rapidly decreasing concentration.***
- b. A patient in shock will have a decreased effect from thiopental.
- c. The anxious patient will require a smaller dose.
- d. The bleeding patient has a faster decrease in brain concentration as a result of the thiopental being lost with effects of hemorrhage.

Appendix C

Student Evaluation- Part I

Student Evaluation- Part I

Student Code # _____

Please indicate which teaching session you attending: (please circle)

Classroom Lecture

Simulator Lab

Please answer the following questions by circling the appropriate response:

Strongly agree	Agree	Neutral	Disagree	Strongly Disagree
(5)	(4)	(3)	(2)	(1)

1. The stated objectives of the course were met. 5 4 3 2 1

2. Lecture material was presented in a well-organized manner. 5 4 3 2 1

3. Please list strengths of the teaching session you attended:

4. Please list weaknesses of the teaching session you attended:

5. Lecturer: (please circle)

Mr. Bill Howie

Mr. John Connelly

-Used effective methods of teaching. 5 4 3 2 1

- Was well-prepared and knowledgeable. 5 4 3 2 1

- Met the stated learning objectives. 5 4 3 2 1

- Any additional comments:

Appendix D

Student Evaluation- Final

Student Evaluation- Final

Student Code # _____

1. Which method of teaching did you prefer? (please circle)

Classroom Lecture

Simulator Lab

Why?

2. Which method of teaching best helped you understand the pharmacology concepts of induction agents?

Classroom Lecture Simulator Lab

Why?

3. Lecturer: Mr. Bill Howie

Used effective methods of teaching.	5	4	3	2	1
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Was well-prepared and knowledgeable.	5	4	3	2	1
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Met the stated learning objectives.	5	4	3	2	1
-------------------------------------	---	---	---	---	---

Any additional comments:

4. Lecturer: Mr. John Connolly

Used effective methods of teaching.	5	4	3	2	1
-------------------------------------	---	---	---	---	---

Was well-prepared and knowledgeable.	5	4	3	2	1
--------------------------------------	---	---	---	---	---

Met the stated learning objectives.	5	4	3	2	1
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Any additional comments:

5. My overall impression of the instruction on Induction Agents:

Poor	Fair	Satisfactory	Good	Excellent
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6. Suggestions for improvement:

Appendix E

Informed Consent for Anesthesia Simulation Study

INFORMED CONSENT FOR ANESTHESIA SIMULATION STUDY

Principle Investigator: Annie L. Hall, Capt, USAF, SRNA

My name is Capt Annie L. Hall. I am a Nurse Anesthesia graduate student conducting research for my Masters' thesis. You are being asked to take part in a research study. Before you

decide to be a part of this research study, you need to understand the risks and benefits to allow you to make an informed decision. This is known as informed consent. This consent form provides information about the research study, which has been explained, to you. After understanding the study and the examinations it requires, you will be asked to sign this form if you desire to participate in the study. Your decision to participate is voluntary. This means you are free to choose to take part in the study.

Purpose and Procedures

The Department of Nursing Anesthesia of the Uniformed Services University of the Health Sciences is conducting this research study to evaluate the effectiveness of the computerized anesthesia human patient simulator in Nurse Anesthesia education. Twelve volunteers will be asked to participate in this research study. The procedure for this study involves each volunteer participating in one of two separate teaching modalities. One teaching session will be conducted in the traditional classroom setting. The second teaching session will be an experiential teaching session utilizing the Human Patient Simulator (HPS) laboratory. The details of the simulator setup and equipment will be explained in detail prior to conducting the teaching session on induction agents. Any questions you may have will be answered.

Benefits

This study will evaluate the effectiveness of the HPS as an effective teaching tool in Nurse Anesthesia education. If proven effective, this high-fidelity method of teaching can become a required component of Nurse Anesthesia curricula. Anesthesia simulators are being utilized in a variety of settings, with the aim of improving provider knowledge and skill in hopes of optimizing patient care.

Time Commitment

There will not be an additional time commitment, as this study will be incorporated in the scheduled Anesthesia Pharmacology course scheduled from 14 May to 22 May 2001.

Risks, Inconveniences, Discomforts

There are no physical risks involved with this study. Your performance on the pre-test and post-test will not be graded nor will it be held against you in any way. Scheduled teaching sessions are planned in advance and can be arranged to accommodate prior commitments.

Students will be asked to anonymously complete two evaluation questionnaires. One questionnaire will be completed following the initial teaching session and after completing the post-examination. The final questionnaire will be completed after finishing the second teaching session.

Cost of Participation

There is no cost to you.

Research Related Injury

This study will not entail any physical or mental risk. If, for any reason, you feel continuing this study will constitute a hardship for you, we will discontinue your participation in the study.

If at any time you believe you have suffered an injury or illness as a result of participating in this research study, you should contact the Office of Research Administration at the Uniformed Services University of the Health Sciences, Bethesda, MD 20814, (301) 295-3303. This office will review the matter with you and provide information about your rights as a participant, and may be able to identify resources available to you. Information regarding

judicial avenues of compensation is available from the University's General Council (301) 295-3028.

Confidentiality of Records

All information provided as part of this study will be confidential and will be protected to the fullest extent of the law. Records and information you provide related to this study will be kept private, accessible only to those persons directly involved in conducting this study and members of the Uniformed Services University of Health Sciences' Institutional Review Board. All questionnaires and forms will be kept in a restricted access, locked cabinet while not in use. However, please be advised that under UCMJ, a military member's confidentiality cannot be strictly guaranteed. To enhance the privacy of your responses, you will not be identified on any of the data collection tools. Reports generated from this study will not divulge your name or identity.

Withdrawal

I understand that I may revoke my consent and withdraw from this study without prejudice at any time during the course of this research study. I have been given an opportunity to ask questions concerning this research study, and any such questions have been answered to my complete satisfaction. Call Capt. Annie L. Hall (301) 217-0192 or Dr. Eugene Levine, Research Committee Chair, (301) 295-1244 with any questions or concerns. If you have questions regarding your rights as a research participant, you should call the Director of Research Programs in the Office of Research at the Uniformed Services University of the Health Sciences (301) 295-3303. This person is your representative and is not involved with the researchers conducting this study.

I do hereby volunteer to participate in a research study designed to evaluate the effectiveness of the anesthesia human patient simulator (HPS) in nurse anesthesia education. The implications of my voluntary participation: the nature, duration and purpose, the methods and means by which it is to be conducted, and the inconveniences and hazards have been thoroughly explained to me by Capt Annie L. Hall. By signing this consent form, you are agreeing that the study has been explained to you and you understand this study. You are signing to take part in this study. You will receive a copy of this consent form for your records.

I have been given the opportunity to ask questions concerning this study, and any such questions have been answered to my full and complete satisfaction.

I willingly give my consent to take part in this study.

Participant's Signature

Date and Time

Participant's Social Security Number

Witness' Signature

Date and Time

I certify that the research study has been explained to the above individual, by me, and the individual understands the nature and purpose, the possible risks, and benefits associated with taking part in this research study. All questions and concerns have been answered to the best of my ability.

Principle Investigator

Date and Time

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